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Impact of Lake Beseka on the Water Quality of Awash River, Ethiopia

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Abstract Untreated discharge from industries, domestic wastes, flower farms, and irrigation runoff are among the major sources of pollution in Awash River. Increasing of unregulated lake water discharge is another indication of water degradation in the AR. The objectives of the study were to better understand the discharge of Lake Beseka (LB) and its impact downstream on the water quality of Awash River (AR). 480 samples were collected from 2008 to 2017 and analyzed for more than 20 parameters e.g.; TDS, EC, pH, alkalinity, chloride, bicarbonates, carbonates at four sampling stations. Results showed that the water quality of the AR downstream of the Lake has shown a decreasing trend from 2013 to 2017. The quality of the river water deteriorating due to the release of unregulated Lake water into the AR. The annual mixing ratios of the Lake water with the AR were 6.67%, 13.98%, 45.83%, 27.67%, and 18.73% from 2013 to 2017. Thus, it is essential to install and implement adequate and affordable technologies in order to regulate and quantify amount of flow into the AR from the Lake. If the Lake water continuously drains at its current rate, it would be difficult to control its water quality deteriorating effect and will cause environmental disasters in water and soil salinity problematic downstream of the lake human habitats and the Amibera Irrigation Farms.

Keywords: *mixing, Lake Beseka, quantified, Awash River, water quality degradation, salinity*

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1. Introduction

In many countries mixing freshwater and saline irrigation water is implemented to solve water scarcity problem. For instance, mixing of industrial wastewater with fresh water was practiced in some countries like the United States, China and Indonesia [1]. In Awash Basin (i.e. Ethiopia) mixing of Lake Beseka's water with Awash River (relatively fresh water) was carried out not to reduce the problem of water scarcity in the basin rather to slow down the rapid expansion of Lake Beseka, LB, before upsetting the surrounding environment and together with aim of diluting the Lake Beseka's water. Yet, in the basin, mixing LB water with the AR has been taking place in the customary way, which is not based on scientific methods with the gauged and calibrated stations from 2007 up to now.

The starting time of Lake Beseka (LB) expansion is not exactly known, historically LB used to cover an area of 3km^2 from the year 1912 up to 1964; however, studies indicate that it initiated to expand related with the early of Metehara mechanized farms around the lake [2,3]. The Lake level has begun to rise since 1964 and the average annual increment is 0.2m. It currently covers an area of about 55.4 km^2(estimated from the Google earth image).

Different studies indicate that the sources for the rising level of the Lake is not only ground water or hot springs rises from the northeastern part of the lake but also the irrigation discharge from Abadir, Nura Era and Fentalie canals water that greatly escalates the water level of the lake [4,5,6,7]. For the past 6 decades, the expansion and water quality deterioration effect of LB were greatly worried in the nearby sugarcane plantation of Methara [4] and downstream of Beseka like Middle Awash (Afar Region, Ethiopia). It is an environmental problem and grown into a great concern for downstream water users and creates a land use and cover, socio-economic and environmental impact even at the regional level (i.e. Afar & Oromia Regions) and also in national level as well.

To curb the problem of the rising level of LB, different types of measurements were taken. Of these solutions made by the government, first, the Ministry carried out the construction of pumping scheme to discharge controlled amount of Lake water into Awash River (AR), using 8 pumps with a total discharging capacity of 1730 l/s (i.e. August, 2006). However, with some drawbacks of the operation of the pumping scheme, due to different reasons, the pumps stopped working unexpectedly that affected its aim of reducing the level of the Lake [8]. Following the Ministry of Water Irrigation and Electricity resource, MoWIE and Water Works Design and Supervision Enterprise, WWDSE tried an alternative to alleviate the expansion of the Lake by draining the water of LB using gravity method since the end of 2011 by discharging maximum 10 m^3/sec of Beseka´s water into AR.

In addition to these, a similar study was conducted by Oromia Water Works Design and Supervision Enterprise, [3], to createa long-lasting solution to the Lake level rise by allowing the Lake to flow into AR with gravity canal system based on the principle of blending ratios.

The water quality of the Lake water was extremely saline with the EC value of about 71400µS/cm in 1961 [4]. For instance its partial physicochemical properties indicate that the cationic dominance of the lake water is Na^+> K^+ (i.e 17800 & 406 mg/L respectively) where as an anionic dominance was seen Cl^-> SO_4^{2-}> HCO_3^- (i.e 5480 > 4680 > 580 mg/L respectively) [4]. Even though the concentration of the major water quality parameters of the Lake water have been declining over the years, the water quality of Lake Beseka is not yet recommendable for irrigation as well as for domestic purposes.

Water for agricultural uses is determined on the basis of the effect of water on the quality and yield of the crops, as well as the effect on characteristic changes in the soil [9]. The quality of irrigation water is determined by its chemical composition and constituents of soluble and insoluble salts, inorganic and organic matter. In effect, the soil salinity increase in direct proportion to the salinity of the irrigation water and the total depth applied [10]. Irrigation water which has high SAR levels can lead to building up of high soil Na levels over time, which in turn can adversely affect soil infiltration and percolation rate [11].

In fact, if draining the Lake water continues in unregulated way, it will be impact the downstream water users in irrigation developments and also the livelihood of the Pastoral people who depend on the water of the river directly for domestic purposes. Unregulated Lake water discharge deteriorates the water quality of the river Awash.AR after LB mix is a major water source for livestock watering, domestic uses and irrigation water for near-by wheat, vegetables, cotton, and sugar plantations [12]. These crops have significant economic importance of the Afar Region and the whole Ethiopia. Finally, the continuous uses of saline water for irrigation might affect people who live downstream of LB directly or indirectly in a number of ways including.

- decrease irrigable or fertile land and land use and land cover
- decrease crop productivity and income benefits
- reduce the quality of the natural environment
- increase farms that become unprofitable
- increase water scarcity for domestic uses

In summary, rapid solutions and immediate mitigation are required to control the releasing of the unregulated amount of Lake water. The Lake water that released into AR has not been controlled by the levels of EC, TDS, Cl^-, Na, F^-, RSC, SAR, and HCO_3^-.

The objective of this study might differ from the earlier studies because the majority of the previous studies were concerned only about the water source of LB and its expansion. While this study is the first paper that might assesses the impact of poor mixing ratios of LB on socioeconomic and environmental disaster on downstream water users and also to better understand the discharge of the lake water, the importance of the river flow when setting blending ratios, and its adverse effect downstream on the water qualities of the AR.

2. Materials and Methods

2.1. Description of the Study Area

This research was undertaken in the middle part of the Awash Basin and covers 4 sampling stations; baseline, flux, impact, and trend stations; particularly in Awash-Awash sub basin (Figure 1). LB is situated in the Middle Valley of Awash at about 195 Km far from the capital Addis Ababa (8°51.5’ N, 39°51.5’ E). The lake is bounded in the north by Fentale Mountain, in the east by Metehara town and Metehara farm, in the south by the Abadir farm. The area of the Lake watershed is about 505 Km^2, out of this 10% of the lake watershed is covered by LB [13,14,15]. The main rainy season occurs from July and September and the minor rainy time happens from March to May [13]. The long-term average annual rainfall, temperature and evaporation of the area are about 543.7mm, 26.5℃ and 2485mm, respectively [4,13,15].

2.2. Conditions for Mixing the Lake Water with Awash River

Mixing is promising in areas where fresh water can be made available in adequate quantities on demand [16]. In fact mixing of the Lake water with AR without pertinent technology and regulated manner is a very complex action, however, Mo WIE tried to discharge the lake water into AR using selected water quality parameters and mixing standards using equation 1. In line with this, the WWDSE also set the following conditions assuring the quality of the mixed water of LB with AR [3].

The following conditions were established based on the water quality data of AR before and after the Lake, and guidelines for interpretation of water quality for irrigation, FAO, Irrigation and Drainage paper 29 [3].

- EC value should not be greater than 450 µS/cm before LB (at SABB)
- EC value should be less than700 µS/cm after LB **(**at SAAB)
- TDS value should not be greater than 450 mg/L at any downstream stations
- SAR value should not exceed *6* at any downstream location
- RSC should not exceed 2.5 meq/L at any downstream stations
- Fluoride value should be less than 2 mg/L at any downstream station;

The Lake water was mixed with the Awash River using pumping and the principle of mass balance or conservation of mass is applied to determine space concentration of a given conservative element. If the volumetric flow rates and concentrations of the conservative element is known both in the Lake water discharge and receiving river, then the rates and concentrations for mixture is given by the mass balance equation as shown below (Eq.1).

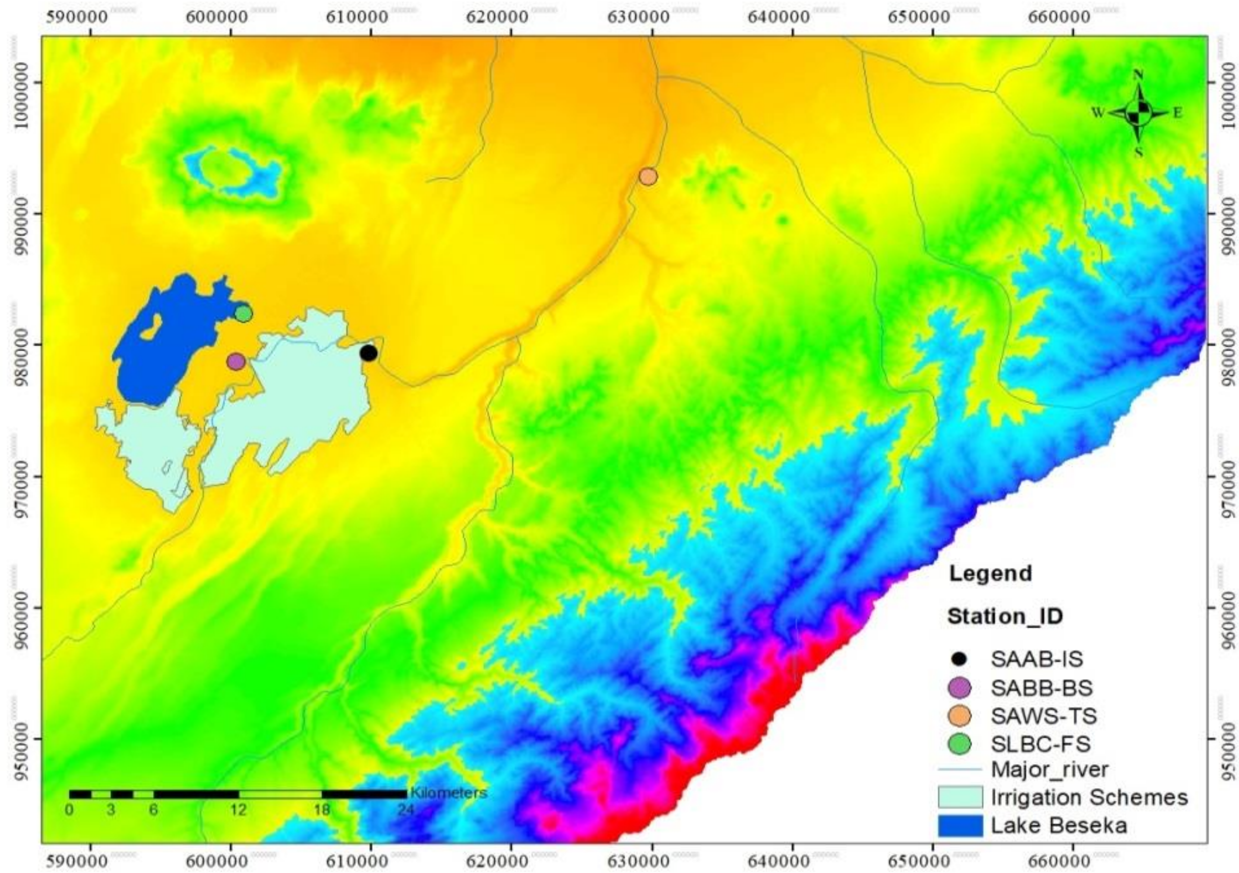

Figure 1. Map of the study Area (NB: SABB-BS, Station Awash before Beseka (baseline station); SAAB-IS, Station Awash after Beseka (impact station); SAWS-TS, Station Awash @ Weir Site (trend station); and SLBC/I-FS, Station Lake Beseka @ Canal or intake (flux station)

$$Q_{sABB}C_{sABB} + Q_{WLBC}C_{wLBC} = Q_{mAAB}C_{mAAB} \quad Q_{mAAB} = Q_{sABB} + Q_{sLBC} \tag{1}$$

Where, Q is volumetric flow rate (AAB-Awash after Beseka, ABB-Awash before Beseka, & LBC-Lake Beseka at Canal)

C is the concentration of EC (where, s-solid, w-water, & m-mix)

The most common parameters the researcher used to determine the irrigation water quality of Awash River are TDS, EC, Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), HCO_3^-, Cl^- and NO_3^- based the standard guidelines of FAO and other considerations [17]. SAR and RSC can be given by the following indexes.

$$SAR = \frac{N_a^{2+}}{\sqrt{\left(C_a^{2+} + M_g^{2+}\right)/2}} \tag{2}$$

$$RSC = \left[HCO_3^{-} + CO_3^{2-}\right] - \left[Ca^{2+} + Mg^{2+}\right] \tag{3}$$

2.3. Data Processing and Analysis

The monthly river water quality data set of multiple water quality parameters from the past 10 years (i.e from 2008 to 2017) at 4 sampling stations; (baseline, flux, impact, & trend stations) were processed using Microsoft Excel 2008 and IBM SPSS 20. SPSS software version 16.0 was used for statistical data analysis and one-way Analysis of Variance (ANOVA) was used to determine statistical differences among sampling stations. Furthermore different graphs (using Grapher-14 software) were used to provide a more meaningful description of the obtained results. In addition, to compare the water quality results some standards like WHO and FAO are used.

3. Results and Discussions

3.1. Summary of the Mixing Efficiency

This study tried to assess the efficiency of mixing ratios of the Lake water with AR and its seasonal variations using equation 1 and also its adverse effect on the water quality and soil salinity problem downstream of the lake. The above-aforementioned conditions of dilution (section 2.2) were considered and established to implement for the water quality of blended water ratios. However, due to various reasons, the recommended conditions were violated in all stated stations.

The expected EC value before the lake stations (i.e. less than 450 µS/cm) from 2013 to 2017 were 437.9, 473.9, 671.6, 526.6 and 478 µS/cm respectively. The increase of EC is due to the discharge from untreated industrial wastewater and sewage from upstream stations [18,19]. Whereas, the value of EC from 2013 to 2017 at SAAB stations were 737.9, 1105, 1417, 1339 and 1111µS/cm which were above the expected values after mixing. This is, because of higher concentration of dissolved ions in the river water that lead to higher EC values in the downstream sites of LB (SAAB-IS).

In the past five years (from 2013-2017), a lack of clear understanding of the mixing ratios and flow of AR and lack of continuous assessment has been one of the reasons for poor mixing efficiency of LB. The data show the water quality deterioration of AR after LB has become worse due to the unregulated water of the lake that drained into AR. This finding clearly indicates the mixing ratio of the Lake water was not governed by the regulator and also the mixing will not be even controlled by manually operated gates. Thus, results revealed that extremely high (poor) mixing efficiency was observed (Figure 2b and Figure 2f) since the mixing practice started.

Even though, the discharge ratio should be 2% of the Lake water into the main course of the river [8], the actual mixing ratio varied greatly from 1.1% (2010) to 45% (2015). The outflows from the Lake that mixed with river water were 18.1%, 25.5%, 17.7%, and 14.8% in 2011, 2012, 2013 and 2014 respectively.

As shown in the Figure 2e the mixing EC ratio of AR with the LB revealed (93.33%**,** 6.67%), (86.02%**,** 13.98%), (55% **,** 45%), (72.37% **,** 27.67%), and (81.27% **,** 18.73%) an increasing trend since 2013 in the last five years. Similarly, the fluoride concentration (Figure 2f) increased due to unregulated water drained into the river and the recorded ratios show (95.62%**,** 4.38%), (92.57%**,** 7.43%), (54.76%, 45.24%), (73.08%, 26.92%), and (80.29%, 19.71%) respectively.

The dilution factor of the Lake violates the recommended mixing ratio unintentionally, and the highest percentage was observed 46% in May-2014 and the lowest value 0.5% in August-2012. The poor mixing practice of the lake water into AR is due to the absence of water regulating device. Thus, as seen in Figure 2e, 2f, and 3b the mixing ratio violates the threshold values expected after blending. Therefore, the dry season (DS) is not a preferable season for dilution due to the insufficient flow of the river water or, a reduced amount of surface runoff.

The past 5 years (from 2013-2017) mixing efficiency of the Lake water was poor; Figure 2a, 2b, 2c, 2d, 2e, and 2f show the poor implementation of mixing ratio of the Lake water into the river and its impact on the water quality degradation of the river water. Hence, this finding clearly illustrates the need for urgent actions to protect the pollution load of the Lake water.

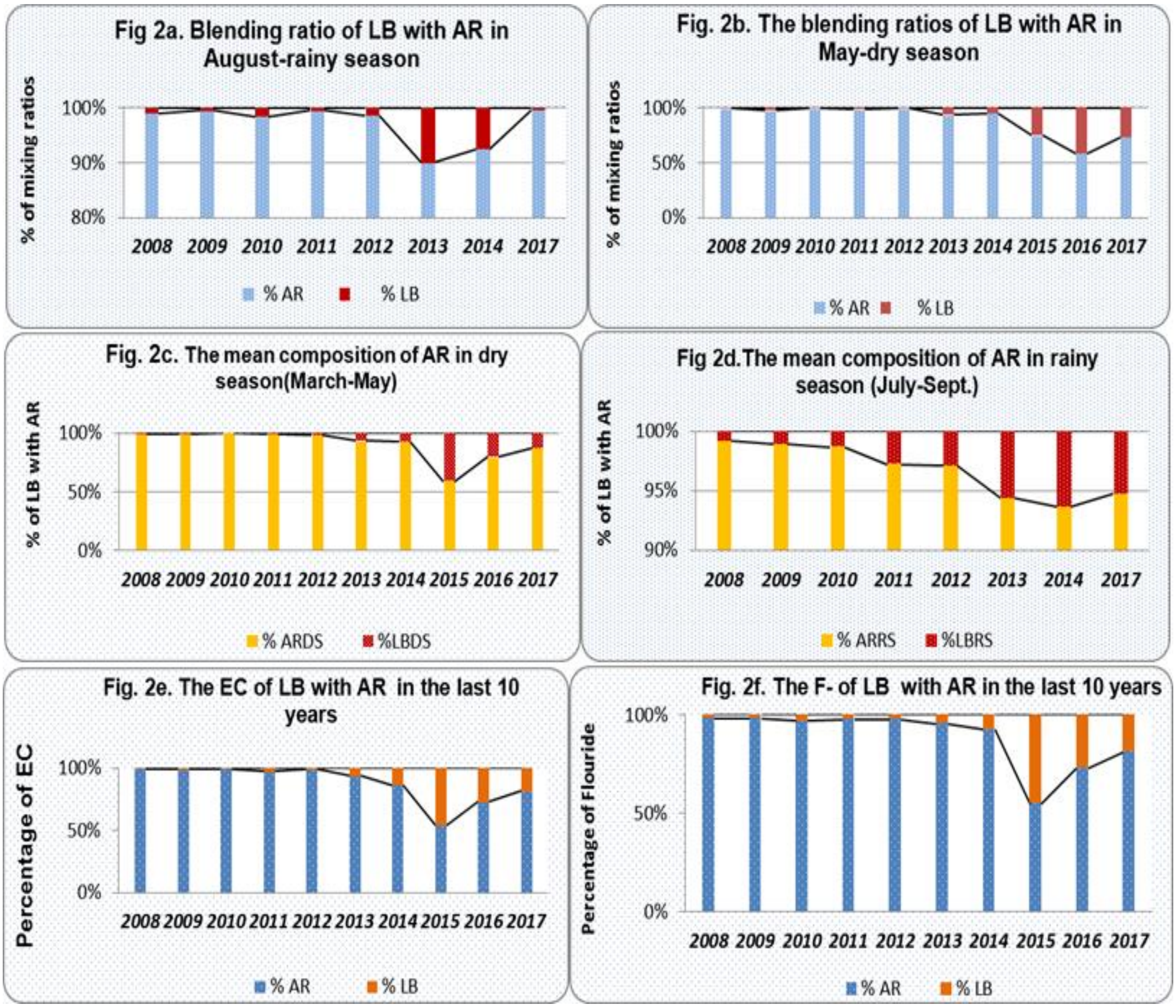

Figure 2. (N.B: Where; ARDS-Awash River Dry Season; LBDS-Lake Beseka Dry Seasons; ARRS-Awash River Rainy Season, & LBRS-Lake Beseka Rainy Season)

3.2. The Flow Variability

The flow of AR varies from the rainy season to the dry season due to rain variability. This seasonal variation significantly affects the water quality monitoring and mixing activities of LB. Particularly the dry season (March, April & May) has low flow due to lack of rain, while in wet season (July, August & September) its flow is high due to high rain and the amount of surface runoff. In rainy season due to high surface runoff a better mixing ratio (dilution factor) was observed as seen in the Figure 3c, 3d, & 3f. Consequently, findings also show that September is relatively the finest month for dilution and has the mean mixing ratios of 2.87% in the last ten years. As shown in Figure 2a, the past ten years data (from 2008 to 2017) of a rainy season, RS; especially in August, the water drained from the Lake into AR is about 2.87% while in a dry season, DS like May it rises into 11.16% average discharge.

In a dry season with limited surface runoff, the river water flow was declined too. Thus, poor mixing ratio practice and excess amount of the Lake water were drained into AR. This higher release rate of the Lake water might add higher masses of conservative substance into the river water and also the dilution capacity of the receiving water (i.e AR) is poor (Figure 2e). Excess ratio of the Lake water particularly on the main dry season (i.e May, or "Ginbot") was seen. This high percentage of the Lake water was also observed at downstream stations as seen in Figure 2b & 2c. In line with this abnormally sunny or dry year like 2015 and partly 2016 the Lake water that drained into the river was recorded beyond the expected ratios with a value of 45.83% and 27.63% respectively (Figure 2e).

Due to poor operational efficiency of manually controlling gates, the mean EC values are slightly higher than the permissible level in March, April, & May (Figure 3b.). Table 2 states the mean EC value in the AR after LB at SAAB-IS and SAWS-TS is higher than the expected threshold level in the aforementioned three months. The outflow from the Lake in the main dry season, DS (May) is mixed with the river water in a percentage of 6.56%, 5.21%, 23.3%, 41.7%, and 26.87% in 2013, 2014, 2015, 2016 and 2017 respectively. Figure 3a & 3c describe the threshold value of EC on AR expected before mixing the Lake water. Here the Figure 3a also imparts the increasing trend of AR.

Figure 3e and 3f show the effect of fresh water that drained from Abadir and Nura Era farms, and Fentallie improved the water quality of LB and also the Lake water has reduced its salinity hazards in the past decades. For instance, the water quality trend of the Lake has been improving dramatically; The EC of the Lake has declined approximately tenfold from 74170µS/cm to 7440µS/cm and sodium from 17800mg/l to 1810mg/l from 1961 to 1991 [4,20,21].

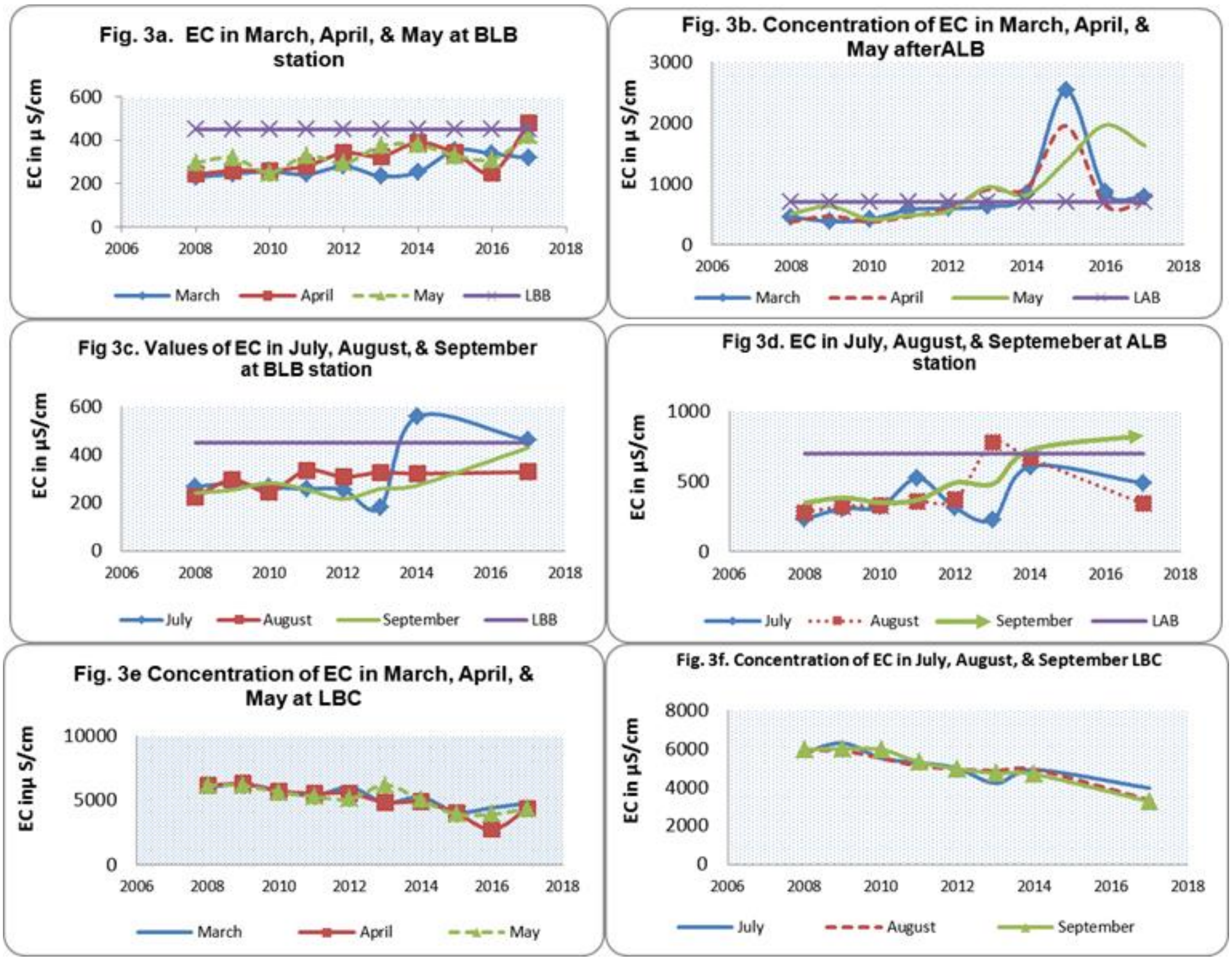

Figure 3. (**N.B:** Where: BLB-Before Lake Beseka; ALB-After Lake Beseka; LBC-Lake Beseka at Canal; LBB-Limit value Before Beseka; & LAB-Limit value After Beseka mix)

3.3. Impact of LB on the Water Quality of AR

The water quality degradation effect of LB on AR was assessed using the last ten years water quality data (from 2008 to 2017). Results of ANOVA test indicate that variation in concentrations was significant across sampling sites. The mean concentrations of Na^+, K^+, Cl^-, SO_4^{2-},and HCO_3^-, after LB were about two-fold greater than before Beseka (Table 1) due to the discharge of the Lake water. The water chemistry of AR after LB is escalating in average two-fold in most water quality parameters.

Table 1. The water quality parameters and their analytical method in this study

Parameters	Units	Instruments/Apparatus
pH	*Unit less*	*Z-WAG-WE 3002pH/Temperature*
EC	*µS/cm*	*5 Series Portable Conductivity/TDS meter*
TDS	*mg/L*	*5 Series Portable Conductivity/TDS meter*
TH	*mg/L*	*Titrationwith0.05 N EDTA*
Mg^{2+},Ca^{2+}	*mg/L*	*Titrationwith0.05 N EDTA*
Na^+, K^+	*mg/L*	*Flame Photometer*
Fluoride, F^-	*mg/L*	*Spectrophotometer HACH*
Chloride, Cl^-	*mg/L*	*Titration using0.014 NAgNO*$_3$
Alkalinity	*mg/L*	*Titrationwith0.01 NH*$_2$*SO*$_4$
Bicarbonate, HCO_3^-	*mg/L*	*Titrationwith0.01 NH*$_2$*SO*$_4$
Ammonia, NH_3	*mg/L*	*Spectrophotometer Hach Company*
Nitrate, NO_3^-	*mg/L*	*Spectrophotometer Hach Company*
Sulfate, SO_4^{2-}	*mg/L*	*Spectrophotometer Hach Company*
Phosphate, PO_4^{3-}	*mg/L*	*Spectrophotometer Hach Company*

As shown in Table 2, the mean EC value has increased in all stations except SLBC-FS, as the mean value of EC, TDS, F^-, SAR, and RSC values in SAAB-IS were exhibited (879 ± 612µS/cm), (512.8 ± 302 mg/L), (3.01 ± 2.62 mg/L), (6.94 ± 5.95) and (4.52 ± 3.77 meq/L) respectively. This is due to the poor mixing ratio, the aforementioned parameters revealed high values than the expected (i.e< 700µS/cm, 450mg/L, 2mg/L, 6 and 2.5meq/L) in downstream stations especially at SAAB respectively.

Results in Table 2 show that the pH value varied 7.92 ± 0.4 in SAAB and 7.9 ± 0.2 in SAWS stations. Station SLBC has a pH value of 9.4 ± 0.2, which is higher than the guidelines of FAO irrigation water standards (6.5-8.5). This may be unsatisfactory and have problems of nutrition or toxicity. The past ten years mean EC value of SABB-BS, SAAB-IS and SAWS-TS showed 435 ±109 µS/cm, 878 ± 611µS/cm, and 748 ± 408µS/cm respectively and it is under permissible limit. High carbonates and bicarbonates (CO_3^{2-}& HCO_3^-) lead to an increase in alkalinity and sodium saturation in soils [16,22].

From 2013-2017 the mean value of EC exhibited; 741µS/cm, 1057µS/cm, 1417µS/cm, 1117µS/cm and 1185µS/cm respectively in SAWS (trend station). The dilution action had not achieved the desired concentration of EC at downstream stations of LB (SAAB & SAWS). Consequently, the chemistry of the river water downstream of the Lake showed the increasing trend and rises beyond the expected limits of conductivity (i.e. 700µS/cm) by WWDSE/OWWDSE.

Table 2. Mean and Standard Deviation of Some Water Quality Parameters from 2008-2017

Parameters	***Sampling Stations***												WHO 2011 4th ed.
	SABB			**SLBC**			**SAAB**			**SAWS**			
	Mean	**±**	**SD**	**Mean**	**±**	**SD**	**Mean**	**±**	**SD**	**Mean**	**±**	**SD**	
TDS	254.3_a	±	45.2	$3,181.2_b$	±	848.6	512.83_a	±	302.27	438.9_a	±	214.1	1000
EC	435.5_a	±	109	$4,978.5_b$	±	886.7	878.87_c	±	611.96	$748.4_{a,c}$	±	408.2	1500
pH	7.4_a	±	0.3	9.4_b	±	0.2	7.92_c	±	0.4	7.9_c	±	0.2	6.5 - 8.5
Ammonia	$.8_a$	±	0.1	$.7_a$	±	0.1	0.77_a	±	0.23	$.7_a$	±	0.1	3
Sodium	42.5_a	±	9.2	$1,134.0_b$	±	389.2	123.16_a	±	106.1	158.2_a	±	155.7	200
Potassium	9.2_a	±	4.2	42.8_b	±	12.5	13.36_a	±	6.84	10.1_a	±	7.2	12
TH	110.9_a	±	16.2	22.5_b	±	7.6	96.77_c	±	12.77	$100.4_{a,c}$	±	12.2	300
Calcium	36.6_a	±	9.4	7.1_b	±	3.6	30.34_c	±	2.97	$31.2_{a,c}$	±	3.6	75
Magnesium	9.9_a	±	5.3	4.1_a	±	3.4	11.01_a	±	7.01	11.3_a	±	8.9	150
Fluoride	1.5_a	±	0.7	17.8_b	±	7.5	3.01_a	±	2.62	2.0_a	±	1.3	1.5
Chloride	21.6_a	±	11.8	375.3_b	±	118.9	42.92_a	±	33.78	47.3_a	±	36.7	250
Nitrite	$.1_{a,b}$	±	0	$.0_a$	±	0.1	$.09_{a,b}$	±	0.07	$.1_b$	±	0.1	3
Alkalinity	185.7_a	±	85.7	$1,627.7_b$	±	521	256.13_a	±	140.77	262.0_a	±	125.9	500
Carbonate	15.8_a	±	24.3	460.2_b	±	157.6	48.0_a	±	52.18	32.2_a	±	44.4	250
Bicarbonate	212.7_a	±	75	$1,083.2_b$	±	400.9	270.55_a	±	107.93	279.2_a	±	91.3	580
Sulfate	13.3_a	±	5.3	422.1_b	±	223.6	46.27_a	±	27.09	30.0_a	±	15.9	250
Phosphate	$.4_a$	±	0.2	2.0_b	±	0.7	$.54_a$	±	0.11	$.7_a$	±	0.3	5
SAR	1.63	±	0.35	99.88	±	55.7	6.94	±	5.95	6.15	±	6.19	------
RSC	1.44	±	1.91	32.41	±	9.55	4.52	±	3.77	3.15	±	2.75	------

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at **p< .05** in the two-sided test of equality for column means. Cells with no subscript are not included in the test. Tests assume equal variances.[1]1. Tests are adjusted for all pairwise comparisons within a row of each innermost sub table using the Bonferroni correction. ***All parameters, except SAR, RSC, Turbidity, EC and pH were expressed in mg/L. RSC, Turbidity and EC were measured by meq/L, NTU and µS/cm respectively while pH and SAR are unit.***

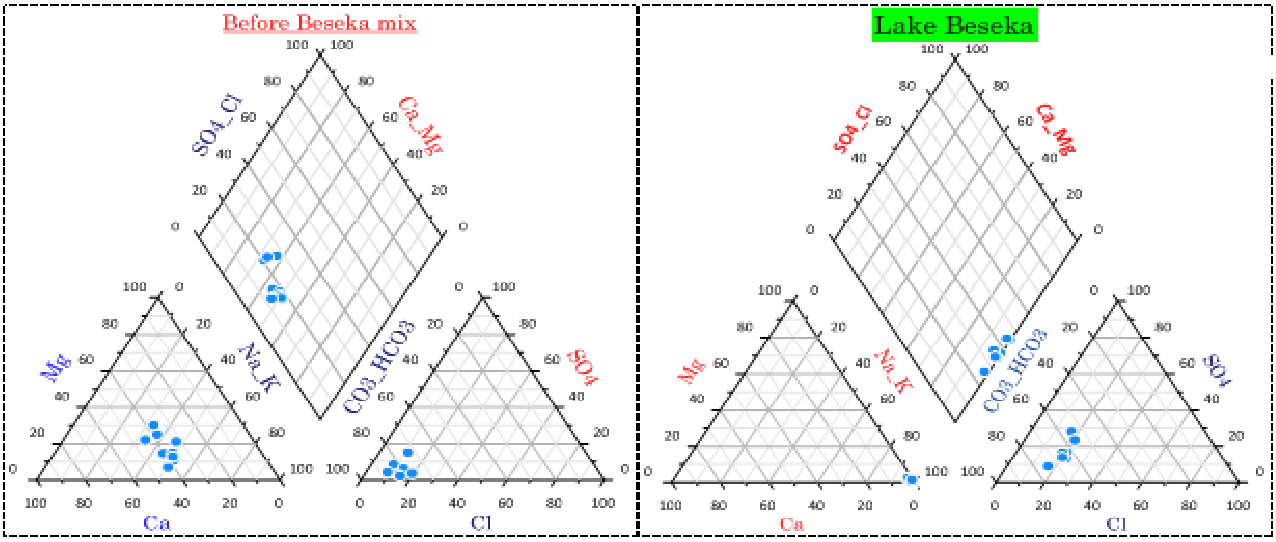

Fig. 4i. Piper diagram of Awash River before Beseka mix. *Fig. 4ii. Piper diagram of Lake Beseka*

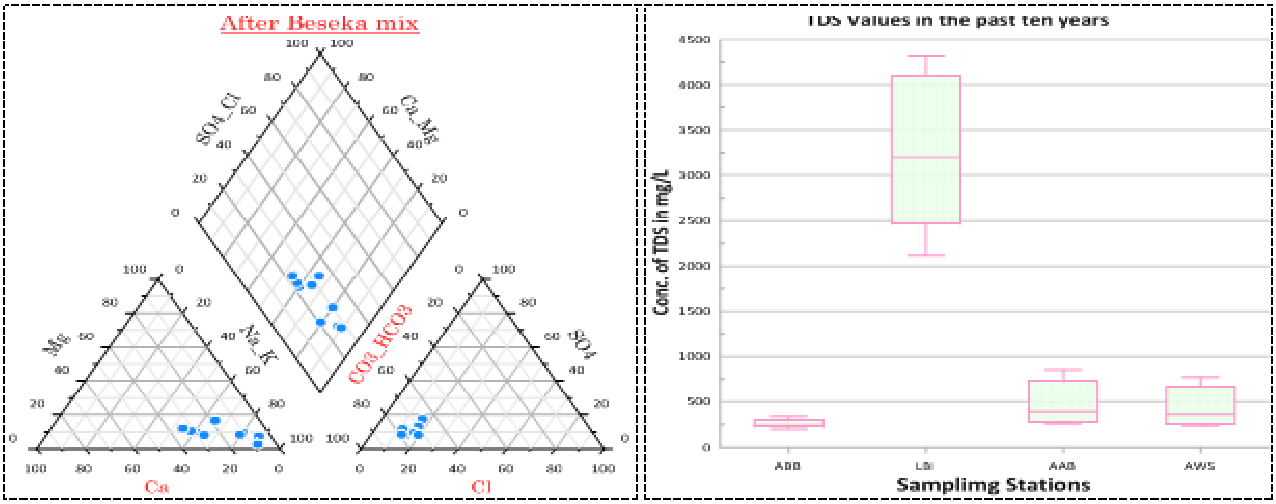

Fig. 4 iii. Piper diagram after Lake Beseka *Fig. 4 iv. TDS using Vertical Box-Whisker Plot*

Figure 4.

Even though there was a positive correlation between SABB-BS and SAAB-IS stations throughout the study time, the cause for the water quality deterioration of AR before LB is significantly different from after Beseka. Rapid urbanization, industrialization, and agricultural runoff are the major sources for the surface water quality deterioration of AR in the upstream side of LB [18]. While, the downstream sampling sites (SAAB & SAWS) are highly affected by unregulated Lake water discharge into AR. The EC values have increased beyond the recommended conditions set by Mo WR/Mo WIE in both stations (SABB & SAAB) (Figure 2c, Figure 3a, & 3b).

In addition Piper diagrams and Vertical Box-Whisker diagram are plotted using Grapher-14 to show different water types in the study area. For instance; as seen in the first piper plot the water type of Awash River before Beseka mix connotes that the right corner of the ternary plot appears to be about 50% Ca^{2+} plus Mg^{2+} and over 80% HCO_3^-. The concentration of $HCO_3^-$is unsuitable and might have severe effect [22]. The right corner ternary diagram of cations in Lake Beseka (Figure 4.ii) imparts 100 % Na^+-K^+ dominance. While, left corner ternary diagram of anions also shows Cl^- -HCO_3^- -CO_3^{2-} dominance. The water quality of the Lake is dominated by Na^+-K^+ (cations) and HCO_3^- -CO_3^{2-} (Anions) and is a sodium bicarbonate water type. Figure 4 iii shows the water type of the AR after Lake Beseka mix is dominated partly by Na^{2+}-Ca^{2+}cations type. While, the anions dominance was seen by HCO_3^--Cl^- types [18,23].

In general the above results clearly show that lack of regular and continuous assessments, unquantified Lake water discharge, lack of regulated flow of AR efficiency and unpractical of modern mixing technologies of LB (Figure 4ii) that drained into the AR affects the river water quality (Figure 4iii) and degrade the water chemistry and the salinity load of the river water (Figure 4i & 4iv).

3.4. Appearing of Salinity Hazard Downstream of LB

Different studies were used different types of measurements to classify the suitability of water for irrigation purposes but, according to Irrigation water quality standards and salinity management strategies, [24] the sodium hazard of water is ranked from low to very high based on SAR values.

Some permissible limits for classes of irrigation water are given in Table 3. Based on this classification the water quality of the river after Beseka mix revealed under permissible class of water quality. Studies prove that the most common source of salts in irrigated soil is the irrigation water itself. This idea is also supported by AGRILIFE Extension-Texas by [24] and stated that the continuous use of class four of water (Table 3) like AR after LB for irrigation uses might degrade the characteristics of soil.

Table 3. Permissible limits for classes of irrigation water

Class of Water Quality		Concentration	
		EC in µS/cm	TDS in mg/L
Class-1	Excellent	250	175
Class-2	Good	250 -750	175 - 525
Class-3	Permissible	750 - 2000	525 - 1400
Class-4	Doubtful	2000 - 3000	1400 -2100
Class-5	Unsuitable	> 3000	> 2100

Source* (AGRILIFE Extension, Texas-2017).

Even though the water quality of AR before LB affected by industrial and domestic waste from big towns and city; the water quality of AR at SABB-TS is characterized under good water class (Table 3). But the water of the river Awash after a few kilometers far after LB mix (station SAAB-IS) showed poor water quality due to unregulated water of LB (Table 2). Therefore, the future risk or level of salinity hazard in Middle Awash partly depends on the water quality of the river Awash; due to unregulated discharge of the moderately saline Lake water that have drained or will continue to flow into AR (Figure 5 &Figure 6).

Unusual conductivity and salinity level are usually indicative of pollution. Soil salinity threat in Middle Awash irrigation scheme is a growing problem and needs assessing its source of salinity downstream of the LB. Yet, it is a complex matter. Because there are a lot of assumptions and practices are likely behind it; the assumption behind this problem is hypostasized and/or might be due to the poor irrigation methods; furrow irrigation, poor land leveling and excess water usage and the water quality of AR due to unquantified LB mix practice that have a significant starring and infuriating role in appearing soil salinity.

Studies indicate that the expansion of the Lake water has affected both the groundwater dynamics and soil salinization of the nearby sugarcane plantation and if it continues, the sustainability of the plantation itself is under a great risk [2,25]. In addition to its expansion, findings of this study revealed that poor mixing efficiency of the Lake water greatly deteriorates the river water of Awash used for irrigation and also aggravates the soil salinity treat since 2013 in Middle Awash (Figure 5 and Figure 6).

Based on Table 4 the water quality of the river is under medium sodium hazard in SAAB and SAWS. Study exemplifies excessive SAR level can lead to soil crusting, poor seedling emergence, and poor aeration [26,27,28,29]. As seen in Figure 5 the value of SAR has showed increasing trend towards the threshold value of FAO limit [30,31] since 2013. In this study, findings revealed that the concentration of sodium was increasing alarmingly after LB and also its adverse effect increases the value of SAR similarly after LB the value of SAR in both SAWS and SAAB exceed the limit of WHO [32].

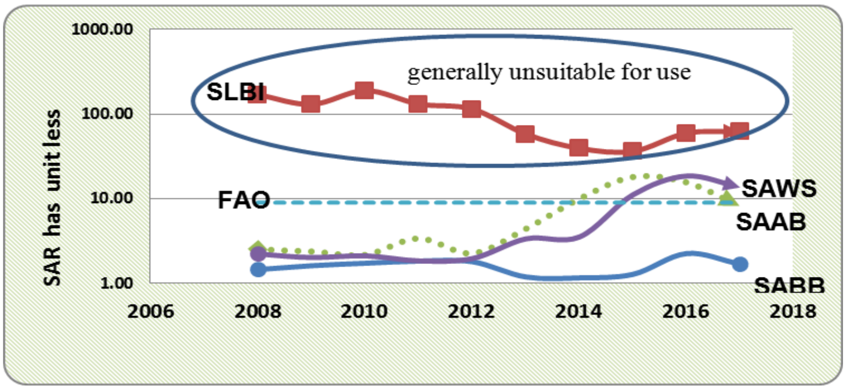

Figure 5. SAR values suspect in irrigation water at downstream stations

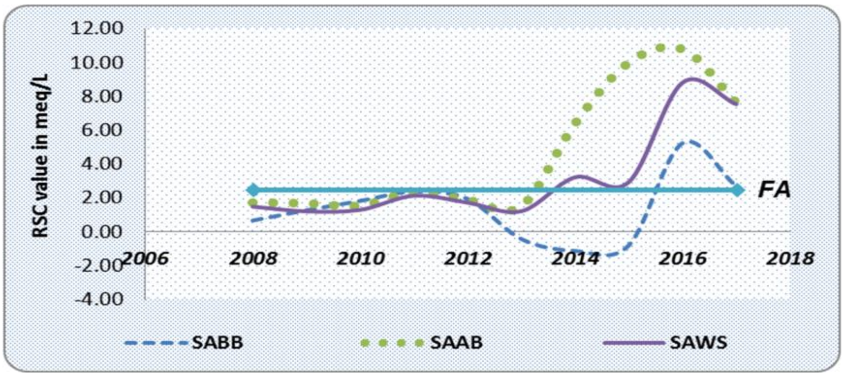

Figure 6. RSC values in downstream of LB stations (from 2008 to 2017)

Table 4. The sodium hazard of water based on SAR values

SAR Values	Sodium hazard of water	Comments
1 - 10	Low	Use on sodium sensitive crops such as avocados
10 - 18	Medium	Amendments (such as Gypsum) leaching needed
18 - 26	High	Generally unsuitable for continuous use
> 26	Very high	Generally unsuitable for use

Source*(AGRILIFE Extension, Texas-2017)

Rao classify water as saline or alkaline (sodic) depending on the ratio of sodium to other dissolved solids; saline water (RSC < 2.5 meq/L) poses a threat to crops due to the concentration of dissolved salts and their effect on soil water matric potential. Whereas, alkaline water (RSC > 2.5 meq/L) poses a threat to soil structure due to the high concentration of sodium in water [33]. Water pollution can have a negative impact on agricultural activities [34]. A negative value of RSC (-1.14 meq/L), in SABB station indicates the total concentration of CO_3^{2-}& HCO_3^- is lower than the combined Ca^{2+} & Mg^{2+} concentrations. This means that there is no residual carbonate to react with Na^+ to increase the sodium hazard in the soil. While, the RSC value is positive in most stations throughout the sampling years (Figure 6); if the RSC value is positive, calcium is lost from the soil solution via the following chemical reaction; carbonates in water reacted with soil calcium and chemically produce calcium carbonate (lime deposit in soil). This loss of Ca from the soil solution would increase SAR in the soil solution, thereby increasing the sodium hazard [34,35].

3.5. General Discussions

Presently, the Awash River Basin is facing environmental problems of unprecedented magnitude due to degradation of the water quality of AR as a result of disposal of industrial effluents, municipal sewage, solid wastes, agricultural runoff, dumping of domestic wastes and natural agents like unregulated Lake Beseka's water discharge.

As seen in this finding the irrigation water used from AR downstream of LB has not been exceeding the limit of FAO/WHO. However, this finding also show that there is the poor average mixing efficiency of LB water into AR during the last five 5 years (from 2013-2017). In fact, the presence of poorly managed irrigation systems; irrigation water, poor land labeling, excess water usage, poor drainage system, water level increment and likes will have serious adverse effects and might increase soil salinity threat at places downstream of LB especially in Middle Awash irrigation area. Thus, the soil salinity problem in Middle Awash has become a growing problem.

In order to assess the pollution load of Awash River due to disposal of unregulated saline water drainage, efforts could not be made to minimize the surplus drainage of the Lake water. However, to reduce the potential water contamination from unregulated water discharge; it needs the implementation of serious measurement and urgent solution on Lake water mixing that might solve the existing serious problem. It also needs proper management and serious solution in water regulations activities. In addition the continuous improvements in the water chemistry of the LB might provide a great opportunity to address the existing water shortage in the basin as well as soil salinity and water quality deterioration threats.

4. Conclusion

The releasing of the Lake water has not been well regulated and has affected the river water chemistry, due to poor implementation of discharging Lake water into the river. It was not governed by the levels of expectations set by WWDSE (2%). Thus, downstream users might suffer from water quality deteriorations and soil salinity. Findings in this study revealed that the dilution action taken failed to achieve the desired concentration of EC, F^-, Cl^-, TDS, pH, and SAR values at downstream stations of the Lake.

The Lake water has significantly detrorated the water quality of the river. The water quality degradations might follow by soil structure deformation, soil salinity, and sodicity effect, along with degradation of livestock watering and domestic uses. The Lake water contributed to the rising level of the water quality deterioration at the downstream stations (i.e SAAB-IS & SAWS-TS) of AR. Thus, the water quality deteriorations of AR after LB might come from four point sources.

- unregulated Lake discharge (Poor mixing efficiency)
- untreated industrial effluents discharge
- sewage discharge, and agricultural runoff into the river

The four sources of potential pollution makes the river water unsafe for drinking uses. However, people live downstream of LB use the water of the river for drinking, cooking, washing their clothes and bodies, livestock watering, irrigation and so on. To solve the problem urgently, the government of Ethiopia (i.e. Mo WIE/BDA) need to learn from the previous shortcomings and should set realistic and pressing solutions to control the water quality degradation effect of AR.

The use of efficient and regulated mixing ratio of the Lake water and regular monitoring systems can minimize many of the problems associated with unregulated and uncontrolled amounts of drainage of the Lake water into the AR. Thus combining the mixing ratio model and Awash River peak flow in the wet and dry seasons might enable better water quality of Awash River at downstream of LB stations.

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Conflicts of Interest

I declare that there are no conflicts of interest in this article.

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